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CORRECTIVE SHOEING OF EQUINE FOOT INJURIES

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INTRODUCTION

Foot injuries are frequently observed in race and sport horses. These injuries are the result of high functional stresses placed on the anatomical structures involved. Therefore, we consider that a major aspect of the management of these conditions is based on the manipulation of the biomechanical stresses of these structures through corrective shoeing.

A specific corrective shoeing program can be set up for each type of bone, tendon and ligament injuries in the equine foot according to:

1. the precise nature of the structure involved,
2. the evolution stage of the lesion and repair process.

The purpose of this paper is to present a summary of our recommendations regarding the corrective shoeing of horses presenting foot injuries. These recommendations are based on clinical and imaging data obtained on clinical cases as well as experimental data obtained from in vivo and in vitro biomechanical studies on the equine distal limb.

I. MANIPULATION OF THE FOOT ORIENTATION IN THE SAGITTAL PLANE

The design of shoes changing the dorsopalmar dynamic balance of the foot is not new (Fig.1).

Manipulation of the foot orientation in the sagittal plane is directly correlated with changes in the biomechanical behaviour of ligaments and tendons (digital flexor tendons and suspensory apparatus) of the distal limb (digit, metacarpus and carpus). Several in vitro and in vivo studies have demonstrated the following associated biomechanical events.

1. Elevation of the heels induces a distal interphalangeal joint (DIPJ) flexion and relaxation of the deep digital flexor tendon (DDFT) and accessory ligament of this tendon (AL-DDFT, distal check ligament) [1-4]. Because of this relaxation, the metacarpophalangeal joint overextends and this movement induces an additional tension of the third interosseous muscle (TIOM, suspensory ligament) and superficial digital flexor tendon (SDFT) [5-7]. Elevation of the heels also induces relaxation of the sesamoidean ligaments of the podotrochlear apparatus (collateral sesamoidean ligaments and distal impar sesamoidean ligament). As the DIPJ flexes and DDFT is relaxed, elevation of the heels decreases the pressure on the distal sesamoid bone.

2. Elevation of the toe induces a DIPJ extension and an increased tension on the DDFT and AL-DDFT. Because of this higher tension, support of the fetlock by these structures is increased and participation of the TIOM (and SDFT) to fetlock support is reduced [2]. Elevation of the toe also induces tension of the collateral sesamoidean ligaments and distal impar sesamoidean ligament. As the DIPJ extends and DDFT is stretched, elevation of the toe increases the pressure on the distal sesamoid bone.

II. SHOEING PROGRAMME FOR DDFT AND PODOTROCHLEAR APPARATUS LESIONS

1. The principles of the shoeing program are:
   a. to reduce strain of tendon sustaining recent injuries, to avoid worsening of the lesion and promote initial healing;
   b. to induce progressive elongation of the tendon, as healing progresses, in order to improve the deformability of the scar tissue. The final goal is to avoid tendon retraction and to reduce the risk of a reinjury since short and thick scar segments predispose the tendon to be reinjured.
   c. The peak of tension of the distal DDT and of its accessory ligament is correlated to the maximal DIPJ extension that takes place at the end of the
stance phase (propulsion phase); therefore, the goal of the shoeing programme is to facilitate the rolling of the toe and avoid DIPJ hyperextension.

2. Application to clinical injuries of the DDFT

a. Trimming

An adequate trimming of the foot is essential before placement of a corrective shoe. Although it must be adapted to each individual horse and each individual foot, the basic aspects include:

• Lateromedial foot balance according to the distal limb conformation;
• Manipulation of the dorsopalmar balance of the foot to reduce static and dynamic DIPJ extension: trimming of the dorsal part of the foot to reduce toe length, increase the toe angle and preserve the height of the heels.

Trimming the distal and dorsal aspect of the toe to facilitate the ultimate dynamic rotation (rolling) at the end of the stance phase.

b. Rolling reverse shoe (RRS)

For recent injuries of the DDFT itself, a rolling reverse shoe (with or without elevation of the heels) is appropriate to reduce dynamic DIPJ extension and strain on the injury (Fig. 2 and 3). This shoe presents a wide transverse support under the heels (e.g. 30-35mm wide for a 550kg horse), progressively narrower branches dorsally and an effective dynamic bevel at the dorsal extremity of the branches. As sport horses often work on circles or turns, to facilitate breakover on the dorsolateral or dorsomedial aspect of the foot, it is important that the bevel extends palmarly on the external margins of the shoe until the middle between the distal toe and heels (Fig. 3). This type of shoe can be made using commercially available shoes (Fig. 4), but in all cases adaptation to the biomechanical objectives of the corrective shoeing must be made, including: wider support under the heels, dorsal rolling, collateral rolling.

This type of shoe is designed for horses working on soft ground. The principle is that the wider part of the shoe (the palmar part of the RRS) has less penetration in the ground that the narrower part of the RRS. Therefore, the RRS has a similar effect on soft ground than elevation of the heels on hard surfaces. This concentration of the ground force reaction on the palmar aspect of the foot requires a soft but reactive (dense enough) footing. The efficacy of dorsopalmar manipulation of the foot balance is considerably reduce in deep footing surfaces because of the lack of ground reaction.

Generally speaking, this shoeing correction should be maintained at least during 2 shoeing periods (0 to 3 months after the initial injury). According to the severity of the injury, ultrasonographic data and clinical signs, the following shoe will be a flat reverse shoe with less palmar support but still a dorsal dynamic rolling of the branches permitting a rehabilitation exercise program (approximately 2 to 6 months after injury). When the lesion is healed, this shoe can be maintained for training and competition in order to prevent from reinjuries.

The above mentioned duration of the different steps of the shoeing program refers to a standardized protocol which should be adapted to each individual case according to the initial severity of the lesion, data obtained from the ultrasound and clinical controls of the healing process, and tolerance of the lesion to each level of physical activity.

c. Rolling reverse shoe vs egg-bar-shoe

The RRS is designed for horses working on deformable ground surface. On this type of footing the wide surface under the heels limits penetration of the palmar part of the foot in the ground. Secondly, as there is no support under the toe region, penetration of the dorsal part of the foot is facilitated during the ultimate part of the stance phase and there is no restriction in the rolling of the foot during the propulsion phase. The RRS combines these 2 effects, and reduces the DIPJ extension from landing to break-over, and therefore reduces the stresses on the distal DDFT. For horses working on hard surfaces, heel elevation can complement the rolling toe.

On an egg bar shoe, very often the palmar surface of the shoe is similar to the dorsal surface (Fig. 5). Secondly, the toe reduces penetration of the dorsal part of the foot at the end of the stance phase and therefore, the egg bar shoe is less effective to reduce DIPJ dynamic hyperextension.

Another advantage of the RRS is the wearing of the foot toe avoiding elongation of the cranial lever-arm of the DIPJ at the end of the shoeing period. Growing of the toe, especially on flat feet is detrimental for an injured podotrochlear apparatus.

On both RRS or egg-bar-shoe a bevel at the most palmar border of the shoe, under the heels, will reduce hell concussion during foot landing and chronic collapse of weak heels (Fig. 6).

d. Heel elevation or not?

We do not recommand heel elevation for primary DDFT lesion in young horses in order to avoid any tendon retraction. Heel elevation is not indicated in horses with weak and collapse heels. For theses feet we recommend to use a pad opened over the frog with firm silicone in the lateral sulci of the frog (paracuneal sulci). Heel elevation is required in old chronic lesions with rigid scar tissue within the DDFT.

3. Other podotrochlear apparatus lesions

These lesions include: distal sesamoid bone injuries, collateral sesamoidean or distal sesamoidean desmopathies/enthesopathies and podotrochlear bursitis. These structures can be responsible alone or in conjunction for acute or chronic lameness. Reduction of the biomechanical stresses on theses anatomical structures is essential for the management of the condition. According to the functional behaviour of the podotrochlear apparatus, this can also be achieved with the RRS providing heel support on soft (but firm, dense) surfaces and facilitating break-over. These dynamic effects reduce DIPJ hyperextension during propulsion.
and limit all the stresses (tension and pressure) on the structures involved in the podotrochlear apparatus.

III. COLLATERAL DESMOPATHIES OF THE INTERPHALANGEAL JOINTS

Corrective shoeing is also an essential part of the management of ligament and joint lesions of the equine distal limb [10]. The precise nature of the joint movements must be considered for corrective shoeing of lame horses and preventive shoeing of sound horses [11]. On lame horses, an adequate trimming and shoeing programme requires a precise diagnosis of each injured structure(s), based on radiography, ultrasonography [12] and/or magnetic resonance imaging (Table 1). Lateromedial and dorsopalmar radiographs proved to be of invaluable interest for the assessment of joints balance for adequate foot trimming.

The goal of the shoeing program of collateral ligament injuries is to reduce tension of the injured structure [13]. This can be achieved through the control of collateromotion, sliding and rotation of the affected joint. For an injury of the medial collateral ligament the corrective shoeing consists in providing more support (wider branch) on the side of the lesion, with improved rolling effect on the opposite (lateral) side (Fig. 7). The opposite is recommended for lateral collateral injuries. When collateral desmopathies are found concomitantly with podotrochlear apparatus injuries, asymmetry of the branches can be done on a reverse rolling shoe (Fig. 8). All the anatomical structures of the distal limb are highly stressed during weight bearing and especially during the stance phase on uneven ground or asymmetric foot placement [13, 15]. Therefore, a soft and regular ground surface is essential for the rehabilitation of distal joint injuries. Turns should also be limited and exercise in lunge is contra-indicated.

CONCLUSION

These shoeing recommendations have been found essential in the management of podotrochlear injuries and collateral desmopathies of the foot in race and sport horses. It emphasizes the role of corrective trimming and shoeing in influencing the biomechanical behaviour of the interphalangeal joints in order to manipulate the mechanical stresses undergone by these structures at each step of the healing process and to facilitate rehabilitation and reconditioning.

ACKNOWLEDGMENTS

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<table>
<thead>
<tr>
<th>Structure involved</th>
<th>Cause of injury</th>
<th>Corrective shoeing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symmetric : DIPJ hyperextension</td>
<td>Long toe-low heels conformation</td>
<td>Reverse Rolling Shoe</td>
</tr>
<tr>
<td>Distal DDFT and/or DDAL</td>
<td></td>
<td>Elevated heels + rolling toe</td>
</tr>
<tr>
<td>Asymmetric infrasamoidean DDFT and/or DDAL</td>
<td>Similar to above + Collateromotion on the injury side</td>
<td>Similar to above + Wide branch opposite to the injury side</td>
</tr>
<tr>
<td>Asymmetric suprasamoidean DDFT and/or DDAL</td>
<td>Similar to above + Collateromotion opposite to the injury side</td>
<td>Similar to above + Wide branch on the injury side</td>
</tr>
<tr>
<td>DISL</td>
<td>DIPJ hyperextension</td>
<td>Reverse Rolling Shoe</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Egg bar shoe with dorsal rolling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Elevated heels + rolling toe</td>
</tr>
<tr>
<td>Asymmetric DISL</td>
<td>Rotation on the opposite side</td>
<td>Narrow branch on the injury side</td>
</tr>
<tr>
<td>Medial collateral ligament</td>
<td>Lateral motion</td>
<td>Wide medial branch</td>
</tr>
<tr>
<td></td>
<td>Medial rotation</td>
<td>Narrow lateral branch with bevel outside</td>
</tr>
<tr>
<td></td>
<td>Lateral sliding of P3</td>
<td>No lateral extension (no wedge)</td>
</tr>
<tr>
<td>Lateral collateral ligament</td>
<td>Mediomotion</td>
<td>Wide lateral branch with lateral extension (wedge)</td>
</tr>
<tr>
<td></td>
<td>Lateral rotation</td>
<td>Narrow medial branch with bevel outside</td>
</tr>
<tr>
<td></td>
<td>Medial sliding of P3</td>
<td></td>
</tr>
<tr>
<td>Osteoarthrosis (Degenerative joint disease)</td>
<td>Secondary to ligament injuries Joint instability Degenerative process</td>
<td>Rolling shoe in : o dorsopalmar direction o lateromedial direction Shock absorbing device</td>
</tr>
</tbody>
</table>

Table 1 - Corrective shoeing of foot injuries
REFERENCES


LEGEND OF FIGURES

Fig. 1 : Old bar-shoe made in 1861 for the treatment of chronic foot conditions inducing foot atrophy (courtesy: Museum of the École Nationale Vétérinaire d’Alfort).


Fig. 2: Steel reverse rolling shoe. The shoe is wider under the heels (top of image) and the branches are progressively narrower dorsally (bottom of image).

Fig. 2a: distal aspect (contact with ground surface)

Fig. 2b: proximal aspect (contact with the foot): the shoe is concave sagittally in order to avoid frog pressure. See the two clips on the side of the dorsal extremity of the branches.

Fig. 2c: the shoe is nailed on the foot. See the dorsal bevel of the branches to facilitate break-over

Fig. 3: Aluminium reverse rolling shoe. The shoe is wider under the heels and the branches are progressively narrower dorsally. See the bevel at the dorsal and external border of the branches extending on all the dorsal part of the shoe to facilitate break over on turns.
**Fig. 4**: Natural balance shoe. When placed in a reverse position (wider sagittal part under the heels) this shoe can be used as a reverse rolling shoe with minimum adaptation (dorsal and collateral bevel).

**Fig. 5**: Conventional egg-bar-shoe. As there is no dorsal and collateral rolling, this shoe is not appropriate for the management of podotrochlear apparatus or DDFT lesions. The heads of the nails are prominent and also reduce rolling during the propulsion phase.
**Fig. 6:** Full rolling egg-bar-shoe. This shoe facilitate the break-over in dorsal and collateral direction. There is not enough palmar support under the heels for a horse with acute or subacute podotrochlear apparatus or DDFT pain. The palmar bevel avoid excessive pressure under the heels; this is appropriate in horses with weak heels and chronic podotrochlear apparatus lesion.

**Fig. 6a:** distal aspect

**Fig. 6b:** lateral aspect. Two clips were elevated in dorsal and collateral positions.

**Fig. 7:** Asymmetric shoe used for the corrective shoeing of collateral desmopathies. The wider branch is placed on the side of the lesion. To avoid tension on the injured ligament, rolling is facilitated on the opposite side with a bevel on the external border of the branch opposite to the side of the collateral desmopathy. The palmar bevel of this branch contribute to concentrate the support of the foot under the lesion.

**Fig. 7a:** distal aspect (contact with ground surface)

**Fig. 7b:** Palmarodistal aspect: see the bevel
Fig. 8: Asymmetric reverse rolling shoe used for the corrective shoeing of asymmetric podotrochlear apparatus lesions or concomitant injuries of this apparatus and collateral desmopathies. On this foot, an asymmetric leather pad was used to increase medial support. The dorsal extremity of the branches and most dorsal nail-heads should be filed lower to improve dorsal rolling.